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United States Department of Agriculture,

BUREAU OF SOILS—CIRCULAR No. 18.

MILTON WHITNEY, *Chief of Bureau.*

THE WIRE-BASKET METHOD FOR DETERMINING THE MANURIAL REQUIREMENTS OF SOILS.

This circular has been prepared to meet the many requests received by the Bureau of Soils for detailed information concerning the wire-basket method for determining the manurial requirements of soils. The method consists in growing plants in small wire pots containing soil to which fertilizers of different kinds and in varying quantities have

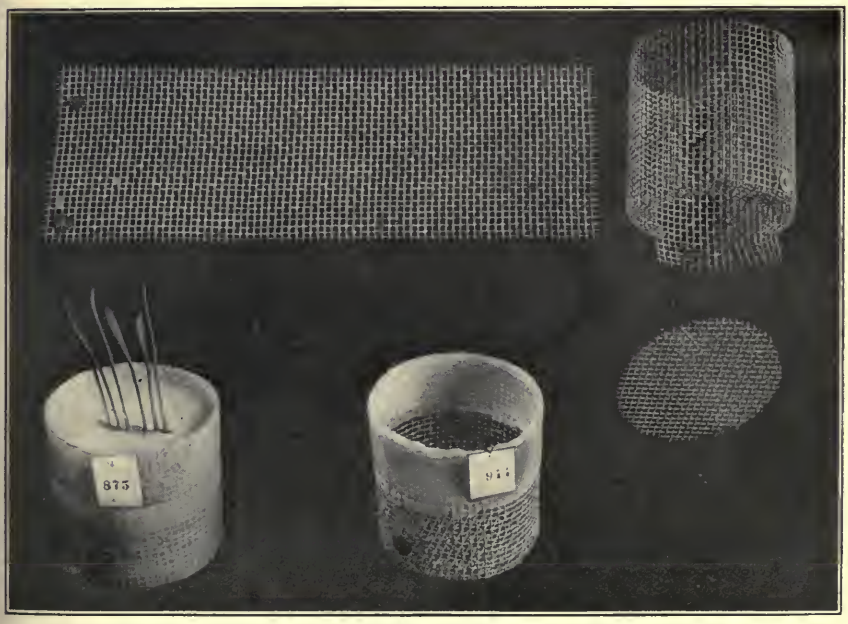

FIG. 1.—Construction of wire basket.

been added. The pots are of peculiar construction and are planned to enable the comparison of the several fertilizing ingredients by actual measurements of the transpiration of the growing plants, though the efficiency of the treatments may also be judged by cutting and weighing the plants at the end of two or three weeks, or in many cases by the appearance of the plants alone.

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In addition to the wire baskets the apparatus necessary for the more scientific work of a laboratory consists of two balances, one having a minimum capacity of one-tenth gram, the other a maximum capacity of about 10 pounds; a graduated cylinder for measuring liquids; several galvanized-iron pans 14 inches in diameter and 2½ inches deep, and some shallow boxes or trays 20 inches long, 16 inches wide, and 1 or 2 inches deep to hold a group of baskets. The baskets or pots are made from galvanized-wire net having one-eighth-inch mesh and are of simple construction (see fig. 1). The net is cut into strips 3½ inches wide by 10 inches long. The ends are brought together and fastened by short rivets. At intervals along one end of the cylinder thus formed vertical incisions one-half inch long are made and the ends turned in to hold the bottom, which consists of a disk of the same material. The top of the basket is then dipped into hot paraffin to the depth of about 1 inch, removed, and dipped again until a rim of paraffin is formed. Numbers are then attached to the pots so that a record of each may be kept, and 20 pots are placed in each tray. This completes the construction of the wire basket up to the time of filling it with soil.

The soil to be examined should be a composite sample made up from a large number of separate samples taken from different parts of the field and very thoroughly mixed together. From this composite sample is weighed out a number of 4-pound portions and each placed in a pan, the number of portions being one more than the number of different treatments which it is desired to try. The soil in the pans is again thoroughly pulverized and to each is added the fertilizer which it is desired to test. The quantity of fertilizing ingredient added should correspond closely to the quantity commonly used in field practice. To one portion of the soil no fertilizer is added, this being used as a check with which to compare the results obtained in the treated soil.

In the greenhouse it has been found most convenient to add manure and lime in the dry form, finely chopped cowpea vines, either green or dry, and the other fertilizers in the form of stock solutions, prepared in such proportion that the desired quantities may be readily determined. It has also been found that the most satisfactory results are often obtained when the fertilizers are added to the soils several days before planting. Dry cowpea vines and undecomposed manure require a certain degree of decomposition before they benefit growing plants, and the time required for lime to show beneficial effects depends on the nature of its principal action in the soil. It is therefore desirable to apply these ingredients two or three weeks before planting. The stock solutions used by the Bureau contain 10,000 parts per million of each of the following salts: $NaNO_3$, K_2SO_4, and $CaH_4(PO_4)_2$, and are made by dissolving 10 grams of the salt in 1 liter

of water. Then 10 c. c. of the stock solution added to 1 kilo of soil, or 18 c. c. added to 4 pounds, represents 100 parts per million or 200 pounds per acre. Quicklime is slaked and added usually at the rate of 1.8 grams to 4 pounds of soil or 1 ton per acre. Manure, if used in the dry form, is usually added at the rate of 9 grams to 4 pounds or 5 tons per acre.

The following table shows the treatments commonly used in the greenhouse work, but these are often varied to suit conditions:

1. Untreated.
2. Dry manure, 5 tons per acre.
3. Lime, 1 ton per acre.
4. Nitrate of soda, 200 pounds per acre.
5. Sulphate of potash, 200 pounds per acre.
6. Acid phosphate, 200 pounds per acre.
7. Nitrate of soda and sulphate of potash, 200 pounds each per acre.
8. Nitrate of soda and acid phosphate, 200 pounds each per acre.
9. Sulphate of potash and acid phosphate, 200 pounds each per acre.
10. Nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each per acre.
11. Nitrate of soda, sulphate of potash, and acid phosphate, 200 pounds each per acre + lime, 2,000 pounds per acre.
12. Cowpeas, 5,000 pounds per acre + lime, 2,000 pounds per acre.

After the fertilizers have been added to the soil it is allowed to remain in the pans for several days, being moistened with distilled water occasionally, and frequently stirred so that the fertilizers may become thoroughly distributed. At the end of this time the soil in each pan is moistened again with distilled water, which is added until the optimum condition, or most favorable moisture content for plant growth, is reached. This varies with different soils, but with a little experience the operator can judge it quite accurately. The soil in each pan is then divided into five nearly equal parts, and each part is placed in a wire basket, care being taken to press the soil well into the bottom and sides of the basket, which should be filled to within about one-half inch of the top. After being filled, the soil which projects through the meshes of the wire is carefully brushed off and the baskets are ready for planting.

One or two days before the time for planting, a sufficient quantity of wheat for the purpose is placed between moist cloths, covered with wet sand, and placed in a favorable place for germination. From these sprouted wheat grains those of uniform size and about the same stage of development are selected, six being planted in a row and to the same depth in each basket. The surface of the soil is then covered to a depth of about one-fourth inch with clean dry sand and the pots dipped bottom down into hot paraffin until an impervious layer is formed over the lower part of the basket connecting with the rim around the top. In coating the basket the paraffin is kept at an even temperature and the basket dipped and quickly removed to allow

the paraffin to harden, when it is dipped again, and so on until the coating has the proper thickness. The baskets are then weighed and placed where they will be under as favorable conditions of light, temperature, and moisture as possible, care being taken to keep the baskets of each set together.

When the plants have reached a height of about 2 inches the baskets are sealed. This is done by cutting a disk of stiff paper just large enough to fit inside of the basket, making an opening in the middle through which the plants may grow, dipping the disk in melted paraffin, placing it over the soil, and fitting it snugly around the plants, so that when water is added it will run down into the opening through

FIG. 2.—Finished baskets and growing plants.

which the plants are growing. When this has been done the disk is sealed to the sides of the basket. This is conveniently done with a glass dropping tube, one end of which is placed in a vessel of hot paraffin, whereupon the liquid enters the tube and is held there by placing a finger over the other end. In this way a small amount of paraffin is transferred to the pot, allowed to escape slowly around the edge of the paper disk, the disk being held down by the thumb and fingers of one hand and the basket slowly revolved. In this way the disk is firmly sealed to the sides of the pot, thus cutting off all avenue for the escape of moisture except through the leaves of the plant.

The weight which has been added to the basket by these processes of coating and sealing is obtained by weighing each basket just before

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and just after sealing, and this weight is added to the weight when they were first planted, which is taken as the optimum condition. At intervals of two or three days during the growth of the plants the baskets are again weighed and the weights recorded, and after each weighing enough water is added to bring the weight slightly above the optimum.

At the end of fifteen or twenty days the plants are cut, weighed, and the weight of each set compared with the weight of the set which received no fertilizer. From the comparisons of these green weights and the comparative transpiration of the plants, as shown by the loss in weight, an estimate of the comparative value of the fertilizer may be made.

In the greenhouse work as carried on by the Bureau of Soils, five baskets are used for each treatment and the total transpiration and green weight for the five taken, thus to a large extent eliminating any error which might arise from accident or inherent differences in the individual seedlings were a fewer number of baskets used in the tests.

To those desiring to use the wire-basket method and having the necessary apparatus, the plan followed by the Bureau of making up stock solutions is recommended. It should be remembered, however, that where commercial fertilizers in which certain parts are not readily soluble are used the solution should be thoroughly shaken before taking out the portion necessary for a treatment. In case no apparatus is available for making the measurements necessary in mixing the stock solutions, the following plan may be used and results of some value obtained, although not so reliable as those obtained by more accurate methods:

To 124 ounces, or 7¾ pounds, of dry, well-pulverized soil add 1 ounce of the desired fertilizer. Mix very thoroughly and pass through a sieve at least twice. To 79 ounces, or nearly 5 pounds more of soil, add 1 ounce of the mixture formed above and mix in the same way. This new mixture contains fertilizer at the rate of 200 pounds per acre. When larger applications are desired, proportionally larger quantities of the first mixture should be taken. Obviously these mixtures should be repeated as many times as there are fertilizers to test, after which the samples of fertilized soil are treated exactly as described in preceding paragraphs. Lime, manure, and cowpea vines, being used in larger quantities than the commercial fertilizer, require a smaller amount of soil in the first mixture in order that 1 ounce may be uniformly required for all treatments. For this purpose 11½, 4, and 1½ ounces of soil will be required in the first mixture for 1 ounce of lime, cowpea vines, and manure, respectively. One ounce of these mixtures added to 79 ounces, or nearly 5 pounds of soil, will furnish these ingredients at the rate of 2,000, 5,000, and 10,000 pounds per acre, respectively. If the 5-pound samples are more than sufficient to fill

5 baskets, a portion may be discarded. It is essential, however, that all baskets contain equal amounts of soil. If the amounts contained in the baskets are unequal, the plants in those containing the largest amounts will make the largest growth, just as those plants which have ample room under field conditions grow larger than those that are crowded. With this in view it is desirable to ascertain the weight of soil required to fill a basket to the desired fullness, then place an equal weight of soil in each basket. Where distilled water is not available for wetting the soils, clean, fresh rain water may be used. Well water should be avoided, as it contains considerable soluble material that might influence the growth of plants, and thus interfere with the results.

Experience has shown that a number of precautions are necessary in order to secure reliable results in this work. In selecting samples great care should be exercised in order to obtain results typical of the field conditions. From 10 to 20 separate samples should be taken, each of the same size and to the same depth, and distributed in different parts of the field. The samples to be tested should be a composite formed by a thorough mixture of these.

Great care should also be exercised in selecting seed of the same size and in the same stage of germination at the time of planting. Careful mulching and paraffining of the baskets is essential to secure reliable results, but sealing is not necessary if transpiration is not to be measured. Uniformity of temperature, light, and moisture for all plants in the test are absolutely necessary, and it is well to change the relative positions of the baskets frequently, thus balancing any unfavorable conditions due to position.

It should be borne in mind that this is a method not for a study of the requirements of plants, but for the fertilizer requirements of soils, in which the plants are used as an indicator. It is therefore not necessary to grow the plants to maturity; in fact, it would not be possible to do so successfully in the small amount of soil used. Where differences occur as a result of the fertilizers they manifest themselves almost from the very beginning of plant growth, and it is not necessary or advisable to grow the plants for periods of time exceeding twenty or twenty-five days from the date of planting the seed.

FRANK D. GARDNER,
In Charge of Soil Management.

Approved:
JAMES WILSON,
Secretary of Agriculture.

MARCH 15, 1905.

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